1982

Survival, Growth, Food Selection, and Alimentary Canal Development of Intensively Reared Walleyes and Yellow Perch

Gregg Alan Raisanen

SURVIVAL, GROWTH, FOOD SELECTION, AND ALIMENTARY CANAL DEVELOPMENT OF INTENSIVELY REARED WALLEYES AND YELLOW PERCH

BY

GREGG ALAN RAISANEN

A thesis submitted
in partial fulfillment of the requirements
for the degree, Master of Science, Major
in Wildlife and Fisheries Sciences
Fisheries Option
South Dakota State University
1982

SURVIVAL, GROWTH, FOOD SELECTION, AND ALIMENTARY CANAL DEVELOPMENT OF INTENSIVELY REARED WALLEYES AND YELLOW PERCH

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Head, Wildlife and
Fisheries Sciences
Department

ACKNOWLEDGEMENTS

I thank the following persons for making this study possible: R.L. Applegate for his assistance throughout the study, P.D. Evenson for statistical advice, C.G. Scalet for reviewing the manuscript; F. Pfeiffer, Valley City National Fish Hatchery, for providing the fish; B.D. Huss, T.P. Loescher, and G.A. Wickstrom who aided in food collection and caring for the fish; J.A. Younk for help in counting the fish; and a special thanks to my wife, Carrie, for drawing the larval fish and for her encouragement throughout my graduate study.

Financial assistance was provided by the South Dakota Cooperative Fishery Research Unit[1] through Dingell-Johnson Project F-15-R and the South Dakota State University Agricultural Experiment Station.

[1]Cooperating agents; South Dakota Department of Game, Fish and Parks, South Dakota State University, and United States Fish and Wildlife Service.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

SURVIVAL, GROWTH, FOOD SELECTION, AND ALIMENTARY CANAL DEVELOPMENT OF INTENSIVELY REARED WALLEYES AND YELLOW PERCH

Abstract

Gregg Alan Raisanen

Five genera of invertebrates, collected from a municipal sewage lagoon, were fed to newly hatched larval walleyes, (Stizostedion vitreum vitreum), and yellow perch, (Perca flavescens), to document survival, growth, food selection, and alimentary canal development of these fishes.

Mean survival of walleyes for the 18 day period after hatching was 14.1%; mean unaccountable mortality was 43.5%. Forty-three percent of the walleyes remaining after 18 days survived an additional 32 days; mean unaccountable mortality was 33.8%. Mean daily length gain over the 50 day period was 0.8 mm/day.

The cladoceran, Moina brachiata, was selected for by walleyes and yellow perch; the copepod, Cyclops vernalis, was initially ingested in the same proportion as fed, but later was selected for; the rotifer, Brachionus sp., was selected against by walleyes but was selected for by yellow perch during the first five days of feeding and was selected against thereafter; the cladocerans, Daphnia magna and D. pulex, and the rotifer, Asplanchna sieboldi, were selected against by walleyes and yellow perch. Initially, significantly ($P < .05$) more organisms were ingested by walleyes collected at 1100 than at 2300 hours; after day 15, more organisms were ingested by walleyes collected at 2300 than at 1100

hours, but there was a significant ($P < .05$) interaction between the time of feeding and day of feeding, indicating that the effect of feeding time on the mean number of organisms ingested by walleyes was dependent upon the day of feeding. Mean number of organisms ingested by yellow perch collected at 1100 hours was significantly ($P < .05$) greater than the mean number ingested by yellow perch collected at 2300 hours. As the fishes grew they ingested progressively larger cladocerans indicating size selection in feeding.

The alimentary canal progressed through a series of changes as the larvae grew. The alimentary canal was completely developed in walleyes (22 mm, total length) by day 32 and was approaching full development in yellow perch (15 mm, total length) by day 32. Invertebrates, collected from a municipal sewage lagoon, appeared to be of adequate size and species to feed walleyes and yellow perch during larval development.

INTODUCTION

Walleyes (Stizostedion vitreum vitreum) and yellow perch (Perca flavescens) are highly valued sport and food fishes. Many populations are limited by insufficient natural reproduction which makes stocking necessary to maintain adequate populations. When stocked, juveniles (>22mm, total length) usually have a higher survival rate than that of larvae and are therefore in greatest demand. The traditional method of rearing walleye and yellow perch juveniles has been to stock newly hatched larvae into ponds and removing the fish after the food supply is exhausted. With this method, production has been variable and limited due to uncontrollable factors and limited pond space. Several hatcheries and laboratories have reared walleye and yellow perch juveniles on prepared diets (Cheshire and Steele 1972; Nagel 1974, 1976a Beyerle 1975; Huh et al. 1976; Reinitz and Austin 1980); however attempts to rear larvae on prepared diets have failed (Nickum 1978).

Some investigators have attempted to rear walleye and yellow perch larvae intensively by feeding them zooplankton collected from lakes (Hale and Carlson 1972; Olsen 1974; Beyerle 1975), but the main problem has been obtaining sufficient food of appropriate size and species for the larvae. Although the food and feeding of walleye and yellow perch juveniles have been extensively studied (Phycha and Smith 1955; Seaburg and Moyle 1964; Wolfert 1966; Priegal 1969; Parsons 1971; Hansen and Wahl 1981), little information is available on the food habits of larvae. The larval stage is a crucial period of development and food availability is a major factor limiting survival (May 1974).

Municipal sewage lagoons produce large quantities of invertebrates that can be used as food to culture fishes. Sampson (1955) stated that microcrustaceans from wastewater stabilization ponds are excellent food for tropical fish. Dewitt and Candland (1971) evaluated Daphnia magna from a municipal waste oxidation pond as food for salmonids, and Applegate (1981) demonstrated that invertebrates from a municipal sewage lagoon were of appropriate size and species to feed muskellunge (Esox masquinongy) larvae. The present study was undertaken to document survival, growth, food selection, and alimentary canal development of walleyes and yellow perch reared intensively by feeding invertebrates collected from a municipal sewage lagoon.

MATERIALS AND METHODS

Experimental Fish

Newly hatched walleyes and yellow perch were obtained from Valley City National Fish Hatchery, Valley City, North Dakota on 7 May 1981. Thirty thousand walleye larvae were counted into nine 115 liter tanks. Three tanks were stocked at a rate of 2000 larvae (15.5/liter) and six at 4000 larvae (35/liter). The lower half of each of three tanks stocked at the 4000 larvae rate was covered in an effort to concentrate the fish into the upper part of the tank (Howey et al. 1980). Tanks were aerated and charcoal filtered city water flowed into each tank at a rate of 0.5 liter/minute. Water temperature initially was 15 C and was gradually increased to 19±1 C by day 6 after hatching. Eighteen days after stocking, all remaining larvae were transferred into two 554 liter tanks with water flow rates of 1 liter/minute. Approximately 2000 yellow perch larvae (estimated volumetrically) were stocked into a 554 liter tank; water flow rate was 1 liter/minute at 19±1 C.

Walleyes and yellow perch were collected at 1100 and 2300 hours each day for 30 days and walleyes were collected at 1100 hours for an additional 20 days. Three walleyes were removed from each tank at each sampling period for 18 days and six walleyes were removed from each tank thereafter; six yellow perch were removed at each sampling period. Night samples were taken by dipping the larvae from the tanks during darkness. All fishes were anesthetized with 0.1% tricane methanesulfonate (MS 222), measured to the nearest 0.5 mm (total length), and preserved in 10% formalin. All fish lengths reported in this paper are in total lengths.

All tanks were cleaned twice daily by siphoning the tank bottom; all dead fish were counted. No disease control measures were undertaken. Tanks were illuminated from 700 to 2000 hours. Light intensity above each tank was measured with a LAMBDA model LI-185 photometer and dissolved oxygen was measured three times weekly with a Hach water quality test kit.

Experimental Food

Food was collected daily from a local (Volga, South Dakota) municipal sewage lagoon with a 153-μm mesh dip net. The food was filtered through a 1050-μm mesh net to remove detritus, predatory insects, and other large invertebrates for the first 16 days and not filtered thereafter. Food organisms were mixed in a 100 liter tank and a 15 ml sample of the food organisms fed at 800 and at 2000 hours was preserved in 4.0% formalin. Food was added to the tanks seven times daily (during light hours) in sufficient quantities to make zooplankton swarms visible during light hours. Approximately twice as much food was added to the tanks stocked with 4000 larvae as those with 2000 larvae.

Identification of Food Organisms

Food organisms were placed in a circular plankton counting chamber and analyzed under a multipower stereomicroscope (14X-60X) equipped with a calibrated whipple disk. Organisms were identified until 500 individuals (not including Brachionus sp.) were counted; the percentage composition of species or genera was calculated to the nearest 0.1%. Additional counts did not noticably change the calculated percentage composition. One hundred Moina brachiata were measured each

day for the first 30 days; 100 Cyclops vernalis and 100 Daphnia magna and D. pulex were measured each day for days 25-50. An estimate of the epizoic rotifer, Brachionus sp., per cladoceran was made by counting the first 100 cladocerans and Brachionus sp. from each sample.

Organisms ingested by the fish were determined by removing the digestive tracts and examining the contents in the tracts of nine walleyes collected at 1100 hours and nine collected at 2300 hours for the first 18 days; six walleyes collected at 1100 hours and six collected at 2300 hours were examined each day thereafter. Five yellow perch collected at 1100 hours and five collected at 2300 hours were examined each day. The contents of the tract from the esophagus to the anal sphincter were examined for walleyes (7.5-19.0 mm long) during the first 23 days and for yellow perch (6.0-15.0 mm long) during the first 30 days; stomachs were then adequately developed and they were examined thereafter. Food organisms were identified to species or genera, and all unfragmented cladocerans and copepods were measured to the nearest 0.06 mm. The percentage composition of species and the percentage composition of different sizes of M. brachiata, D. magna and D. pulex, and C. vernalis were calculated. Cladocerans were measured from the anterior edge of the head to the posterior edge of the carapace and from the dorsal edge to ventral edge of the carapace; copepods were measured from the anterior edge of the head to the posterior edge of the caudal ramus and from the lateral edge of the metasome to the other lateral edge.

Alimentary Canal Development

Drawings of each phase of larval development were facilitated by use of a stereomicroscope equipped with a whipple disk. The abdominal

walls, gills, and livers were removed and the larvae and their exposed alimentary canals were drawn to scale. Terminology developed by Snyder (1976) was used to describe different larval fish developmental phases.

Data Analysis

The linear forage ratio (L) (Strauss 1979) was used to determine selection of walleyes and yellow perch for species and various sizes of invertebrates. This index $L = r - p$, where r is the relative abundance of prey in stomach and p is the relative abundance in food sample was calculated and the associated variance determined. Values of L range from +1 to -1 (+100 to -100 when expressed as a percentage), with positive values indicating selection for a food type and negative values indicating selection against a food type. Each value was tested for significant departure from zero and for significant differences between 1100 and 2300 hours by placing a 95% confidence interval around each value. Analysis of variance was used to test differences in survival and unaccountable mortality (percentage of fish that were not accounted for at the end of the study) between stocking rates and between covered and uncovered tanks for the first 18 days. It was also used to test for differences between the mean number of food organisms ingested by fish collected at 1100 and 2300 hours. The Waller/Duncan K-Ratio test was used to test for differences in mean number of organisms ingested by fish stocked at the different densities and in covered and uncovered tanks.

RESULTS

Survival and Growth of Walleyes

The fish remained healthy thoughout the study; no disease problems were observed. Dissolved oxygen was always greater than 4.0 mg/l, and light intensity above each tank ranged from 340-420 lux during lighted hours.

There were 4,230 (14.1%) of the 30,000 larvae present after 18 days (972 fish were removed for food habit analysis); mean unaccountable mortality was 40.0% (Table 1). Mean survival and unaccountable mortality of larvae stocked at 2000 and 4000 fish/tank, and in covered and uncovered tanks did not differ significantly ($P < .05$) (Appendix Tables 1 and 2). Tanks stocked at 4000 larvae and not covered had the highest mean survival (22.7%) and lowest mean unaccountable mortality (26.4%). Of the total mortality, 30.0% occurred within the first three days after hatching before exogenous feeding. Cannibalism was a major factor contributing to the unaccountable mortality. Cannibalism was first observed on the seventh day after hatching and continued throughout the study. An estimate of the percentage of dead fish with only a head remaining during days 10 and 11 was 8.7% (walleye cannibals ingested siblings tail first; they did not ingest the heads). Also, 3.7% of the alimentary canals examined during the first 12 days of feeding contained walleyes. Of the 4,230 larvae present after 18 days, 1813 (42.9%) of the fish were present after an additional 32 days (502 fish were removed for food habitat analysis); mean unaccountable mortality was 33.8%.

The fish increased in mean length from 7.5 mm on the first day

Table 1. The number of walleye (Stizostedion vitreum vitreum) larvae surviving and unaccounted for after 18 days of rearing, 7 May-25 May 1981. Percentages appear in parentheses.

	No. Stocked	No. Surviving	No. Unaccounted
Treatment 1			
	2000	16 (-)[a]	-
	2000	632 (31.6)	536 (26.8)
	2000	15 (0.8)	1121 (41.4)
TOTAL	6000	663 (16.2)	1657 (41.4)
Treatment 2			
	4000	916 (22.9)	956 (23.9)
	4000	823 (20.6)	1174 (29.4)
	4000	980 (24.5)	1039 (26.0)
TOTAL	12000	2719 (22.2)	3169 (26.4)
Treatment 3			
	4000C[b]	18 (0.4)	2244 (56.1)
	4000C	340 (8.5)	1787 (44.7)
	4000C	490 (12.2)	1332 (33.3)
TOTAL	12000	848 (7.1)	6363 (53.0)
GRAND TOTAL	30000	4230 (14.1)	11187 (40.0)

[a]Tank overflowed and was not used for analysis.

[b]Lower one-half of the tank was covered.

after hatching to 46.6 mm on day 50 after hatching (Table 2). Mean daily length gain of the fish for the 50 day period was 0.8 mm. Mean daily length gain for the first 21 days was 0.4 mm but increased to 1.0 mm for the remaining 29 days. Yolk was absorbed by day seven after hatching. The fish were in the larval period for 32 days after hatching and then progressed to the juvenile period.

Selection for Species of Food Organisms by Walleyes

The cladocerans, Moina brachiata, Daphnia magna and D. pulex; the copepod, Cyclops vernalis; and the rotifers, Asplanchna sieboldi and Brachionus sp. were fed to the walleyes. Brachionus sp. was not included in the data analysis because it was not utilized by walleyes. The food selection data were divided into three time periods based on changes in the mean percentage composition of organisms.

All larvae were feeding by day seven after hatching. Moina brachiata was the most abundant organism fed to the fish during the first 24 days of feeding and was selected for by walleyes collected at 1100 and at 2300 hours (Table 3). Daphnia magna and D. pulex, and A. sieboldi were selected against at both 1100 and 2300 hours. Cyclops vernalis was ingested in the same proportion as available during the first 24 days of feeding and was selected for on days 25-45 when no M. brachiata was fed.

The mean number of organisms ingested by larvae collected at 1100 hours was significantly ($P<.05$) greater than for larvae collected at 2300 hours during the first 12 days of feeding (Appendix Table 3). A total of 574 organisms were removed from 108 larvae collected at 1100 hours (mean 5.3/fish) and 439 organisms from 108 larvae collected at 2300 hours (mean 4.1/fish). During the next 12 days of feeding, significantly

Table 2. Mean weekly total length (mm), 95% confidence interval, and length range of walleyes (Stizostedion vitreum vitreum) reared intensively, 7 May-26 June 1981.

Time period	No.	Total Length	
		Mean ± 95% Confidence interval	Range
Hatch	10	7.5	7.0-8.0
Week 1	84	9.2±.15	8.0-10.5
Week 2	84	11.0±.25	9.0-14.0
Week 3	84	14.4±.41	11.0-20.0
Week 4	84	19.1±.54	11.0-26.0
Week 5	84	26.1±.67	20.0-35.0
Week 6	84	33.1±.77	25.0-41.0
Week 7	84	39.3±.72	32.0-49.0
50 days	25	46.6±3.84	36.0-74.0

Table 3. Mean percentage composition of organisms fed to walleyes (Stizostedion vitreum vitreum), mean percentage composition of organisms in gut, and mean linear forage ratio (L) at 1100 and 2300 hours for the first 45 days of feeding, 12 May-25 June 1981.

Days of feeding		Moina brachiata		Daphnia magna and D. pulex		Cyclops vernalis		Asplanchna sieboldi	
		1100h	2300h	1100h	2300h	1100h	2300h	1100h	2300h
1-12	% Fed	79.0	80.5	16.0	14.3	3.4	3.9	1.6	1.3
	% Gut	94.0	97.8	0.8	1.1	5.2	1.1	0	0
	L	+15.0*	+17.3*a	-15.2*	-13.2*a	+1.8	-2.8*a	-1.6*	-1.3*
13-24	% Fed	48.8	49.9	31.3	27.5	19.6	22.3	0.3	0.3
	% Gut	70.9	66.1	8.3	12.8	20.5	12.1	0.2	0
	L	+22.1*	+16.2*a	-23.0*	-14.7*a	+0.9	-1.2	-0.1	-0.3*a
25-45	% Fed	0	-	65.7	-	33.4	-	0.9	-
	% Gut	-	-	56.7	-	43.2	-	0.1	-
	L	-	-	-9.0*	-	+9.8*	-	-0.8*	-

*Significantly different from 0 ($P<.05$).

[a]Significant difference between 1100 and 2300h ($P<.05$).

($P < .05$) more organisms were ingested by larvae collected at 2300 hours than at 1100 hours (Appendix Table 4). A total of 699 organisms were ingested by 72 larvae collected at 2300 hours (mean 9.6/fish) and 512 organisms were ingested by 72 larvae collected at 1100 hours (mean 7.1/fish). There was a signficant ($P < .05$) interaction between day of feeding and time of collection indicating that the effect of time of collection on the mean number of organisms ingested by larvae was dependent upon the day of feeding (Fig. 1). Also, the mean number of organisms ingested by larvae in the covered tanks (mean 3.9/fish) was significantly (K-Ration=100) less than the mean number ingested by larvae in the uncovered tanks (mean 5.3 and 4.9/fish) during the first 12 days of feeding.

Size of Food Organisms Ingested by Walleyes

As the larvae grew, the size of cladocerans ingested increased (Table 4). At first feeding, larvae mean length was 9.3 mm and mean diameter and length of cladocerans ingested were 0.45 and 0.75 mm. By day 45, walleyes mean length was 42.0 mm and mean diameter and length of cladocerans ingested increased to 1.44 and 2.10 mm. Although progressively larger cladocerans were ingested by larvae as they grew, there was no significant ($P < .05$) difference in mean diameter and length of C. vernalis ingested between days of feeding. There was no apparent relationship between fish size and mean size of C. vernalis ingested (Table 5).

Linear forage ratios were calculated for different sizes of M. brachiata for the first 25 days of feeding and for D. magna and D. pulex, and C. vernalis for days 26-45, to determine if the fish were selecting

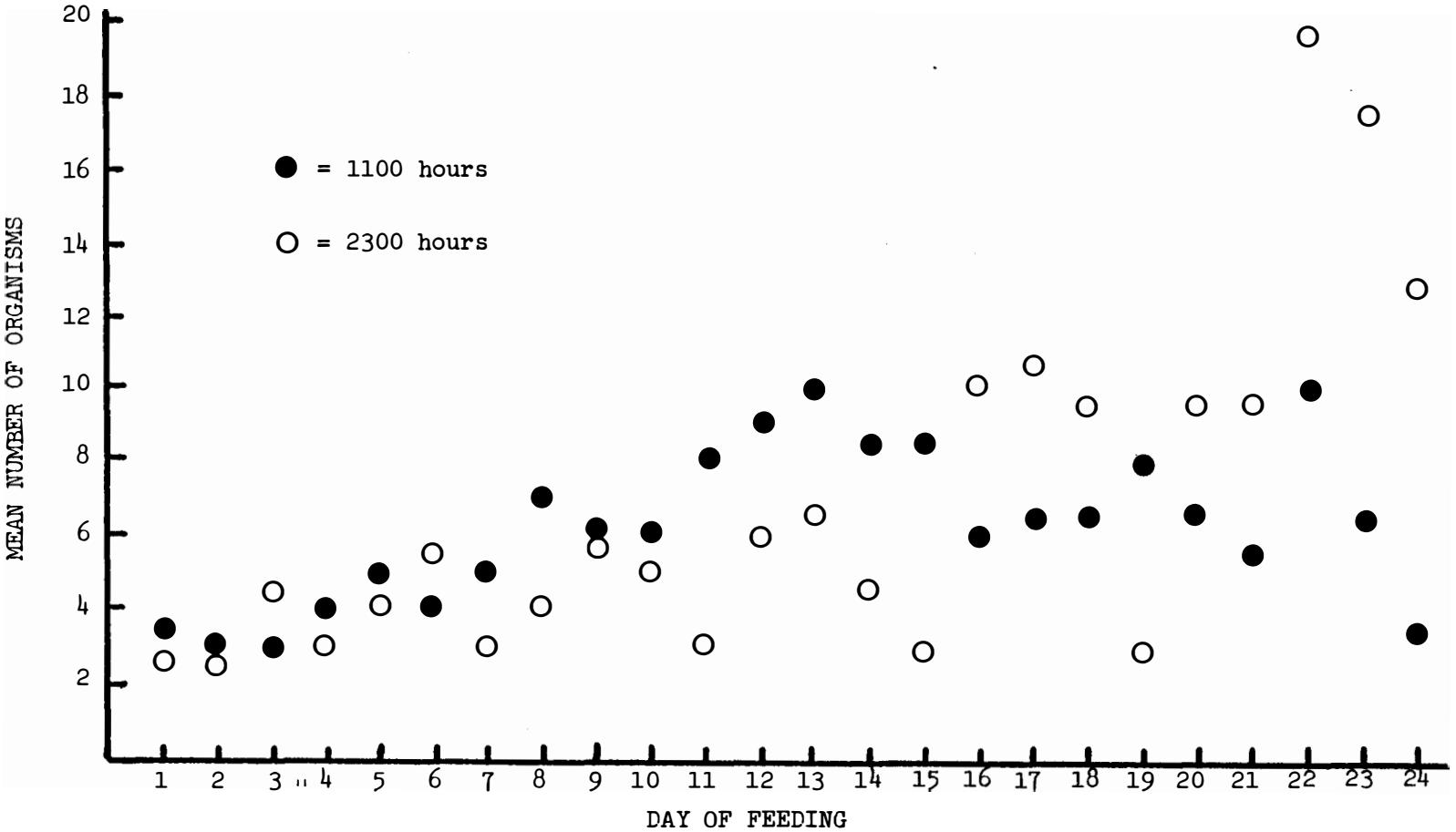

Fig. 1. Mean number of organisms ingested by larval walleyes (Stizostedion vitreum vitreum) collected at 1100 hours and at 2300 hours for the first 24 days of feeding, 12 May-4 June 1981.

Table 4. Mean total length of walleyes (Stizostedion vitreum vitreum) and mean diameter and length of cladocerans ingested during the first 45 days of feeding, 12 May-25 June 1981.

Walleyes			Cladocerans				
				Diameter(mm)		Length(mm)	
Days of feeding	No.	Mean total[a] length(mm)	No.	Mean[a]	Range	Mean[a]	Range
1-5	90	9.3-10.7	111	0.45-0.50	0.28-0.76	0.75-0.85	0.48-1.20
6-10	90	11.1-13.5	280	0.48-0.52	0.30-0.84	0.86-0.91	0.48-1.38
11-15	87	14.0-16.0	387	0.50-0.59	0.36-1.02	0.91-1.03	0.60-1.98
16-20	60	16.3-18.8	318	0.63-0.70	0.42-1.44	1.05-1.20	0.72-2.40
21-25	60	21.0-23.9	339	0.72-0.82	0.30-1.68	1.20-1.38	0.54-2.70
26-30	30	25.0-29.2	69	0.82-1.02	0.30-1.98	1.42-1.74	0.60-3.20
31-35	30	28.5-34.7	73	0.86-1.33	0.30-2.10	1.46-2.15	0.54-3.00
36-40	30	35.3-37.7	95	0.92-1.37	0.30-2.28	1.52-2.17	0.60-3.30
41-45	30	39.7-42.0	214	1.09-1.44	0.30-2.10	1.72-2.30	0.60-3.50

[a]Lower value is the mean for the first day indicated and upper value is the mean for the last day indicated.

Table 5. Mean total length of walleyes (Stizostedion vitreum vitreum) and mean diameter and length of Cyclops vernalis ingested during the first 45 days of feeding, 12 May-25 June 1981.

Walleyes			Cyclops vernalis				
				Diameter(mm)		Length(mm)	
Days of feeding	No.	Mean total[a] length(mm)	No.	Mean[a]	Range	Mean[a]	Range
1-5	90	9.3-10.7	0	-	-	-	-
6-10	90	11.1-13.5	8	0.42-0.54	0.42-0.54	1.32-1.56	1.32-1.56
11-15	87	14.0-16.0	20	0.37-0.48	0.24-0.54	1.17-1.40	0.76-1.68
16-20	60	16.3-18.8	54	0.41-0.49	0.27-0.60	1.35-1.48	0.90-1.80
21-25	60	21.0-23.9	127	0.38-0.44	0.24-0.60	0.94-1.37	0.78-1.20
26-30	30	25.0-29.2	46	0.24-0.41	0.24-0.54	0.94-1.33	0.66-1.62
31-35	30	28.5-34.7	46	0.29-0.39	0.24-0.42	0.95-1.21	0.84-1.50
36-40	30	35.3-37.7	120	0.29-0.35	0.24-0.48	0.98-1.17	0.80-1.50
41-45	30	39.7-42.0	102	0.29-0.31	0.24-0.44	1.01-1.02	0.84-1.50

[a]Lower value is the mean for the first day indicated and upper value is the mean for the last day indicated.

different sizes of organisms. Moina brachiata 0.70-0.96 mm long were selected for by walleyes during the first 15 days of feeding (Table 6). On days 16-25, M. brachiata 0.98-1.24 mm long were selected for, smaller sized M. brachiata were ingested in the same proportion as available, and larger sized M. brachiata were selected against. Linear forage ratios indicated that the walleyes selected for larger sized M. brachiata at 2300 than at 1100 hours.

The fish selected for larger sizes of D. magna and D. pulex as they grew during days 26-45 of feeding (Table 7). Daphnia magna and D. pulex less than 2.00 mm long were selected for, D. magna and D. pulex 2.01-2.50 mm were either selected against or ingested in the same proportion as fed, and D. magna and D. pulex 2.51 mm or longer were selected against on days 26-35. On days 36-45, the fish ingested D. magna and D. pulex less than 1.50 mm long in the same proportion as fed, selected for D. magna and D. pulex 1.51-2.50 mm long, and selected against D. magna and D. pulex 2.51 mm or longer.

Although walleyes selected for progressively larger cladocerans as they grew, they did not select for progressively larger copepods on days 26-45 of feeding. Walleyes selected for C. vernalis 0.76-1.00 mm long, ingested C. vernalis less than 0.76 mm long in the same proportion as fed, and selected against C. vernalis longer than 1.00 mm on days 26-35. On days 36-45, C. vernalis less than 0.76 mm long were not ingested, and all C. vernalis longer than 0.76 mm were either ingested in the same proportion as fed or selected for.

Alimentary Canal Development of Walleyes

The alimentary canal progressed through a series of changes as

Table 6. Percentage of different size Moina brachiata in the alimentary canals of walleyes (Stizostedion vitreum vitreum) (r%) and linear forage ratio (L) for the first 25 days of feeding.

Moina brachiata			Day of Feeding									
			1-5		6-10		11-15		16-20		21-25	
Diameter (mm)	Length (mm)		1100h	2300h	1100h	2300h	1100h	2300h	1100h	2300h	1100h	2300h
< .36	< .68	r	24.6	27.3	14.9	6.5	1.7	1.2	5.5	2.8	1.6	2.1
		L	-13.2*	-0.3[a]	-15.7*	-19.3*	-2.3	-1.8	-3.1	-13.0*[a]	-0.4	+0.5
.42-.54	.70-.96	r	68.6	54.5	75.0	75.0	61.5	69.5	16.6	0.7	3.2	2.1
		L	+39.8*	+16.1*[a]	+32.0*	+32.4*	+38.7*	+45.5*	+8.0*	-8.9*	-0.2	+0.5
.60-.90	.98-1.24	r	14.0	18.2	8.9	13.9	36.0	28.1	63.4	74.3	16.7	17.7
		L	-6.2	-3.6	-11.3*	-13.5*	-19.2*	-17.9*	+46.6*	+56.9*[1]	+12.1*	+12.9*
> .78	> 1.26	r	0	0	1.2	4.6	0.8	1.2	14.5	22.2	78.6	78.1
		L	-13.2*	-12.4*	-5.0*	0[a]	-17.2*	-25.8*[a]	-51.5*	-35.0*[a]	-11.4*	-13.9*

*Indicates significantly different from 0 ($P<.05$).

[a]Indicates significant difference between 1100 and 2300h ($P<.05$).

Table 7. Percentage of different size Daphnia magna and D. pulex and Cyclops vernalis in the alimentary canals of walleyes (Stizostedion vitreum vitreum) (r%) and linear forage ratio (L) for days 26-45 of feeding.

Daphnia magna and D. pulex			Days of Feeding			
			26-30	31-35	36-40	41-45
Diameter (mm)	Length (mm)		1100h	1100h	1100h	1100h
< 0.96	< 1.50	r	46.4	38.4	15.8	25.6
		L	+26.4*	+23.6*	+0.4	-3.6
0.96-1.38	1.51-2.00	r	34.8	20.5	20.0	24.4
		L	+15.4*	+11.1*	+8.6*	+18.6*
1.20-1.56	2.01-2.50	r	11.6	26.0	49.5	29.8
		L	-9.4*	+1.6	+28.1*	+14.6*
1.62-2.10	2.51-3.00	r	5.8	15.1	12.6	19.0
		L	-12.6*	-23.7*	-33.8*	-23.4*
> 2.10	> 3.00	r	1.4	0	2.1	1.2
		L	-19.8*	-12.4*	-3.3	-6.2*
Cyclops vernalis						
< 0.24	< 0.75	r	4.8	0	0	0
		L	-3.0	-0.8	-5.0*	-7.5*
0.24-0.36	0.76-1.00	r	57.4	52.2	35.0	48.4
		L	+33.8*	+34.4*	+8.7*	+1.9
0.30-0.42	1.01-1.25	r	32.5	34.8	47.5	37.9
		L	-13.9*	-22.6*	-1.8	+8.4*
0.36-0.48	1.26-1.50	r	7.0	13.0	17.5	12.5
		L	-1.6	-4.8	+1.5	-3.0
> 0.48	> 1.50	r	2.2	0	0	1.1
		L	-12.2*	-6.2*	-3.3	+0.1

*Indicates significantly different from 0 ($P < .05$).

the larvae grew. Protolarvae were 7.5 mm long on the first day after hatching. A large yolk sac was ventral to the alimentary canal; an oil globule was anterior to the yolk sac. The esophagus connected to a slight bulge at the anterior end of the intestine; no stomach could be detected (Fig. 2A). By day 4, the yolk sac and oil globule were reduced in size, and the alimentary canal had increased in diameter; the intestine began folding anteriorly and laterally at the posterior end of the bulge (Fig. 2B). By day 7, the intestine had folded anteriorly to form a loop; the beginning of the stomach could be detected at the posterior end of the esophagus (Fig. 2C). By day 11, the fish had completed transition to the mesolarvae phase (12.2 mm); the yolk sac and oil globule were completely absorbed and fin rays were developing in the caudal fin (Fig. 3A). By day 14, fin rays had developed in the dorsal and anal fins and the notocord had flexed upward in the caudal fin; the stomach had enlarged and one pyloric caecum was developing posterior to the stomach (Fig. 3B). By day 18, more rays had developed in the median fins, spines began developing in the first dorsal fin, and the fin folds were reduced or eliminated; the stomach had enlarged and the intestine had increased in length and began folding anteriorly and laterally (Fig. 3C). By day 22, more ray elements had developed in the median fins, a second pyloric caecum had developed, and a third was developing laterally to the stomach; the alimentary canal folded anteriorly to complete another loop (Fig. 4A). By day 25, the larvae completed transition to the metalarvae phase (20.0 mm), and pelvic fins had started to develop; more ray elements had formed in the median fins and the stomach had enlarged (Fig. 4B). By day 28, the metalarvae were completing transition to the

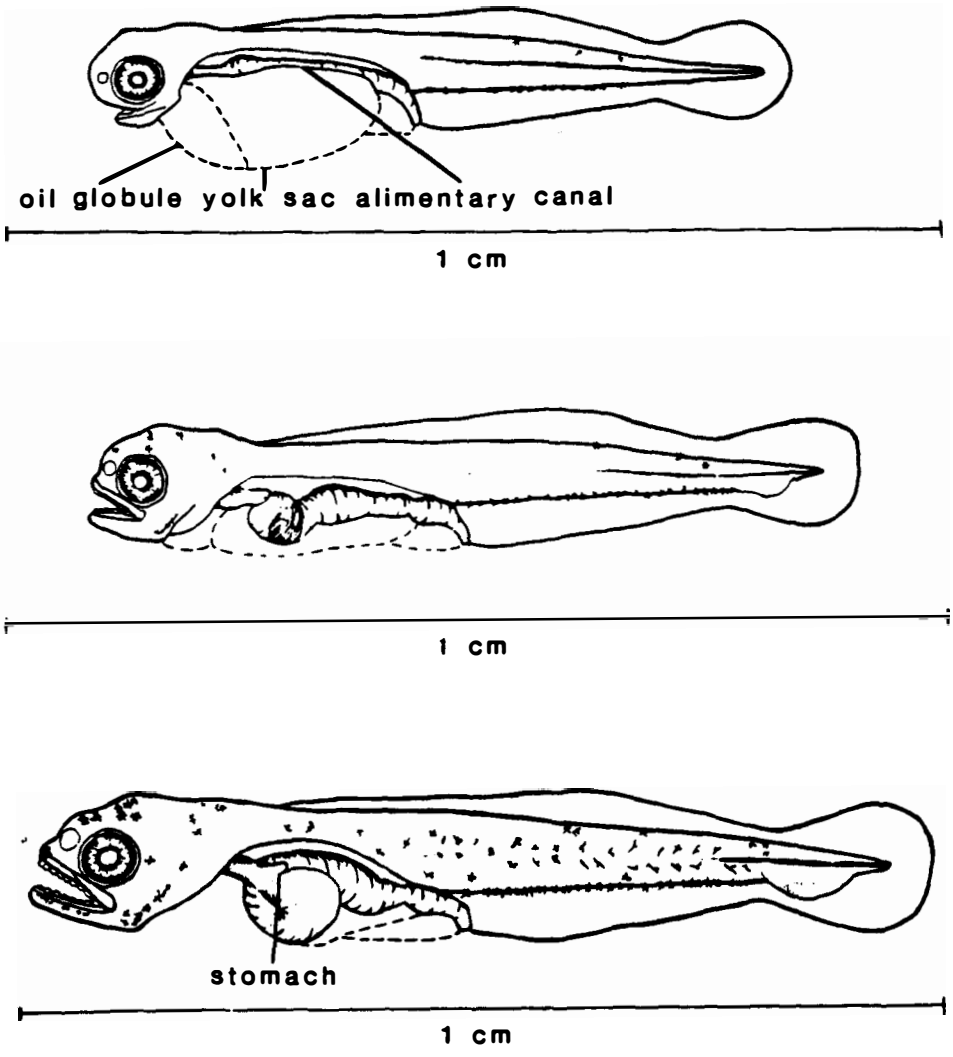

Fig. 2. Alimentary canal development of walleye (Stizostedion vitreum vitreum) larvae: (A) Newly hatched protolarvae, 7.5 mm; (B) Protolarvae, 8.2 mm; (C) Late protolarvae, 9.8 mm (abdominal walls, gills, and livers removed).

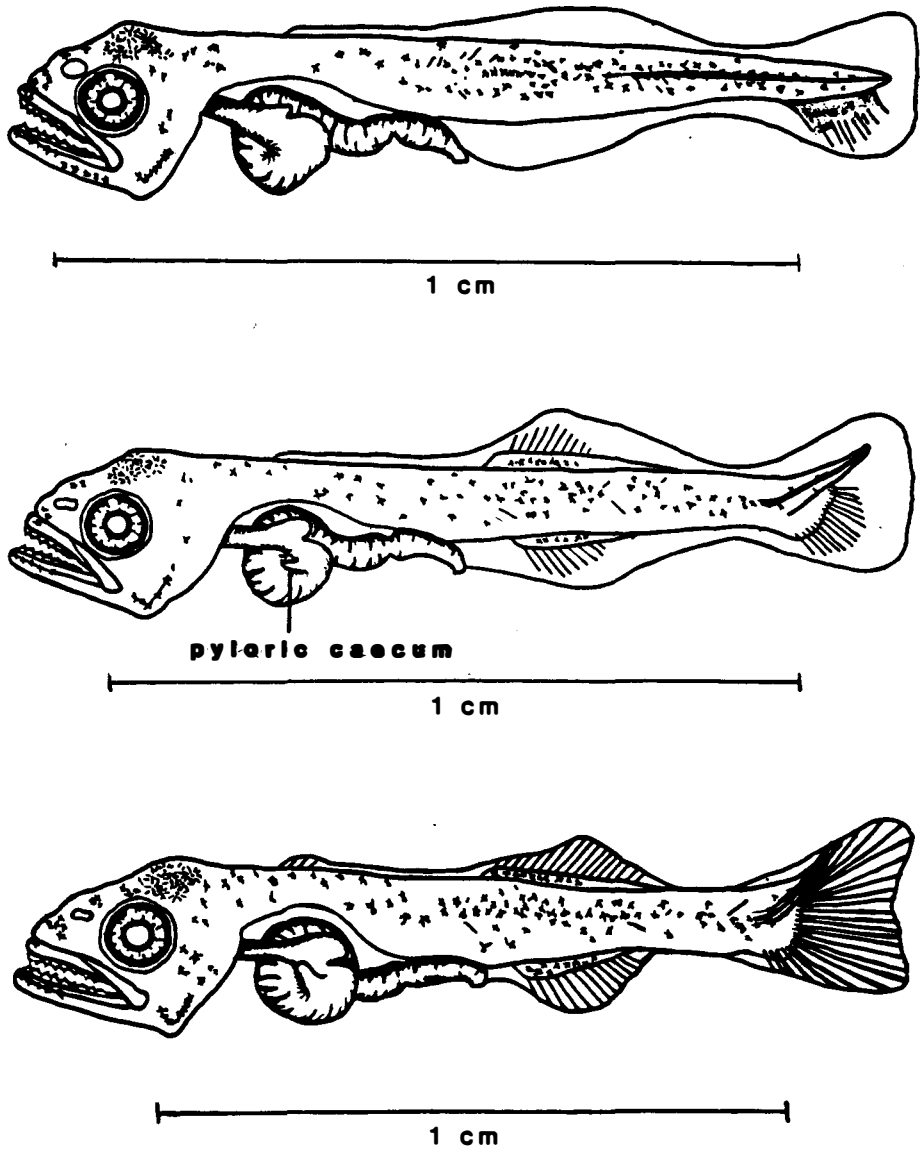

Fig. 3. Alimentary canal development of walleye (Stizostedion vitreum vitreum) larvae; (A) Recently transformed mesolarvae, 12.2 mm; (B) Mesolarvae, 13.0 mm; (C) Mesolarvae, 14.1 mm (abdominal walls, gills, and livers removed).

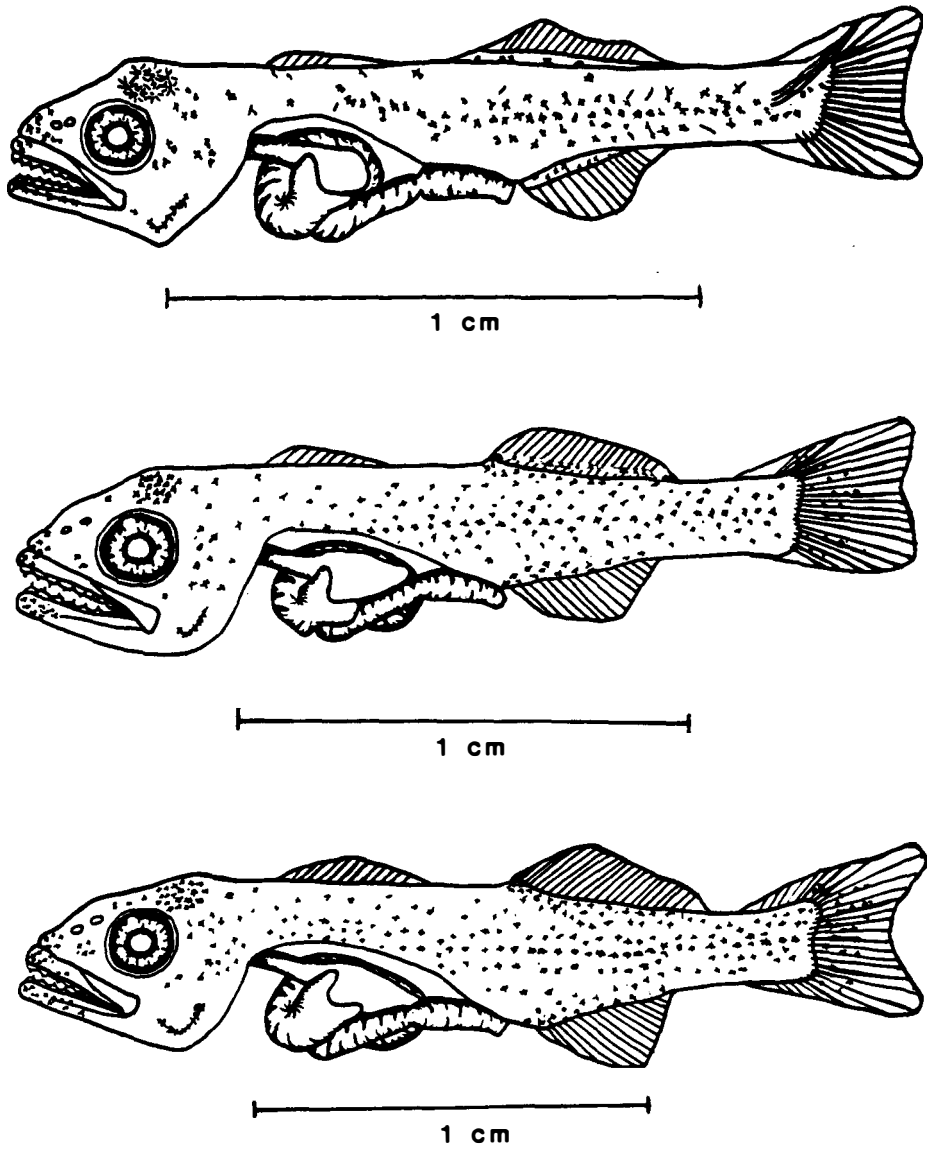

Fig. 4. Alimentary canal development of walleye (Stizostedion vitreum vitreum) larvae; (A) Late mesolarvae, 17.4 mm; (B) Recently transformed metalarvae, 20.0 mm; (C) Late metalarvae, 22.2 mm (abdominal walls, gills, and livers removed).

juvenile period; all fin rays and the alimentary canal had developed (Fig. 4C).

Yellow Perch Food Selection

The same genera of organisms were fed to yellow perch as those fed walleyes. First feeding occurred eight days after hatching; larvae had a mean length of 6.0 mm. The mean number of Brachionus sp./cladoceran in food samples ranged from 0.8 on the first day of feeding to 19.0 on the 22 day of feeding. Brachionus sp. composed greater than 50.0% of the percentage composition of the food fed and was selected for by larvae collected at 1100 hours during the first five days of feeding; it was selected against by larvae collected at 2300 hours (Table 8). During the remainder of the study, Brachionus sp. comprised a majority of the food ingested but was selected against by larvae; it was significantly ($P < .05$) more selected against at 2300 than at 1100 hours. Moina brachiata was selected for on days 6-20 and was significantly ($P < .05$) more selected for by larvae collected at 2300 than at 1100 hours during the first 10 days of feeding. Cyclops vernalis was ingested in the same proportion as available on the first 10 days of feeding and selected for thereafter by larvae collected at 1100 hours. Cyclops vernalis was significantly ($P < .05$) more selected for at 2300 than at 1100 hours on days 6-20. Daphnia magna and D. pulex, and A. sieboldi were selected against by larvae at 1100 and at 2300 hours.

As the yellow perch grew, the size of cladocerans ingested increased. Mean diameter and length of cladocerans ingested increased from 0.20 and 0.36 mm at first feeding to 0.34 and 0.57 mm by the 20th day of feeding (Table 9). There was no significant ($P < .05$) difference

Table 8. Mean percentage composition of organisms fed to yellow perch (Perca flavescens), mean percentage composition of organisms in gut, and mean linear forage ratio (L) for the first 25 days of feeding, 12 May-5 June 1981.

Days of feeding		Brachionus sp.		Moina brachiata		Daphnia magna&pulex		Cyclops vernalis		Asplanchna sieboldi	
		1100h	2300h	1100h	2300h	1100h	2300h	1100h	2300h	1100h	2300h
1-5	% Fed	50.6	59.2	34.0	30.4	12.4	8.7	2.1	1.3	1.0	0.4
	% Gut	83.1	19.4	22.2	80.6	0	0	1.6	0	0	0
	L	+32.5*	-39.8*a	-11.8*	+50.2*a	-12.4*	-8.7*	-0.5	-1.3*	-1.0*	-0.4*
6-10	% Fed	85.9	67.4	12.8	28.9	0.8	2.4	0.3	0.7	0.3	0.6
	% Gut	61.7	14.3	36.9	82.8	0	0	0.1	2.8	0	0
	L	-24.2*	-53.1*a	+24.1*	+53.9*a	-0.8*	-2.4*	-0.2	+2.1*a	-0.3*	-0.6*
11-15	% Fed	70.1	57.4	23.6	34.1	4.2	4.8	1.7	3.3	0.4	0.3
	% Gut	50.0	12.8	28.9	42.6	0.5	0	20.6	44.7	0	0
	L	-20.1*	-44.6*a	+5.3	+8.5*	-3.7*	-4.8*	+18.9*	+41.4*a	-0.4*	-0.3*
16-20	% Fed	80.3	77.5	13.2	15.4	3.8	3.2	2.5	3.8	0.1	0
	% Gut	39.1	12.0	51.1	58.0	0	0	9.9	30.0	0	-
	L	-42.2*	-65.5*a	+37.9*	+42.6*	-3.8*	-3.2*	+7.4*	+26.4*a	-0.1	-
21-25	% Fed	85.2	90.9	4.4	3.0	6.9	3.7	3.4	2.4	0	0
	% Gut	59.5	64.3	2.8	2.7	1.2	0.9	36.4	32.1	-	-
	L	-25.7*	-26.6*	-1.6	-0.3	-5.7*	-2.8*a	+33.0*	+29.7*	-	-

*Indicates significantly different from 0 ($P<.05$).

aIndicates significant difference between 1100 and 2300h ($P<.05$).

Table 9. Mean total length of yellow perch (Perca flavescens) and mean diameter and length of cladocerans ingested by larvae during the first 20 days of feeding, 12 May-31 May 1981.

Yellow perch			Cladocerans				
				Diameter(mm)		Length(mm)	
Days of feeding	No.	Mean total[a] length(mm)	No.	mean[a]	range	mean[a]	range
1-5	37	6.0-6.5	22	0.20-0.22	0.20-0.24	0.36-0.40	0.34-0.44
6-10	50	6.8-7.5	86	0.22-0.26	0.20-0.40	0.38-0.44	0.36-0.64
11-15	49	8.3-9.4	88	0.26-0.32	0.20-0.48	0.44-0.55	0.34-0.80
16-20	48	9.2-10.8	85	0.26-0.34	0.20-0.72	0.45-0.57	0.40-1.26

[a]Lower value is the mean for the first day indicated and upper value is the mean for the last day indicated.

between mean diameter and length of cladocerans ingested by larvae collected at 1100 and at 2300 hours (Appendix Table 5).

Although the mean size of cladocerans ingested by yellow perch collected at 1100 and at 2300 hours did not differ, the mean number of organisms ingested by larvae collected at 1100 and at 2300 hours differed significantly ($P < .05$) (Appendix Tables 6 and 7). A total of 654 Brachionus sp. were ingested by 120 larvae collected at 1100 hours (mean 5.5/larvae) and 104 Brachionus sp. were ingested by 120 larvae collected at 2300 hours (mean 0.8/larvae). A total of 542 organisms other than Brachionus sp. were ingested by 120 larvae collected at 1100 hours (mean 4.5/larvae) and 238 were ingested by 120 larvae collected at 2300 hours (mean 2.2/larvae).

Alimentary Canal Development of Yellow Perch

The yellow perch alimentary canal progressed through a series of changes as the fish grew. Gas bladder development was also included in the drawings since it was prominant and developed from the esophagus. Three days after hatching, the yolk sac and oil globule were ventral to the alimentary canal in the protolarvae (5.7 mm). The alimentary canal was a straight tube; a slight bulge present on the dorsal surface of the esophagus was the beginning of the gas bladder (Fig. 5A). Complete yolk sac and oil globule absorption occurred by day 10. Little change could be detected in the alimentary canal by day 14 except that it had enlarged and the beginning of the ductus pneumaticus could be detected (Fig. 5B). By day 21, fin rays began developing in the caudal fin; the larvae had completed transition to the mesolarvae phase (10.9 mm). The alimentary canal began folding anteriorly and laterally; the gas bladder was

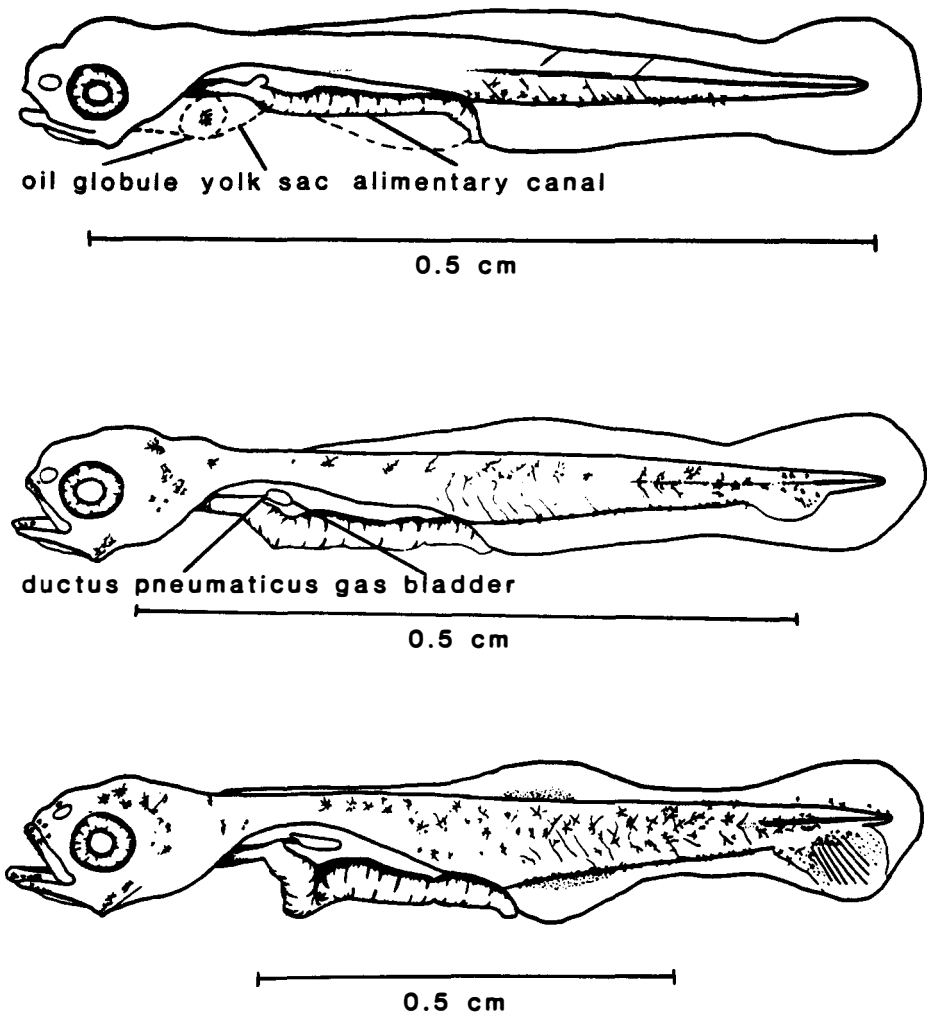

Fig. 5. Alimentary canal development of yellow perch (Perca flavescens) larvae; (A) Early protolarvae, 5.7 mm; (B) Protolarvae, 6.9 mm; (C) Recently transformed mesolarvae, 10.9 mm (abdominal walls, gills, and livers removed).

seperated from the alimentary canal and connected to it by the ductus pneumaticus (Fig. 5C). By day 25, more rays had developed in the median fins and the notocord had flexed upward in the caudal fin; the alimentary canal had increased in length and the gas bladder had enlarged (Fig. 6A). By day 26, more rays had formed in the median fins; the alimentary canal had folded anteriorly to form a loop and the beginning of the stomach could be detected (Fig. 6B). By day 28, the finfolds had reduced in size or were eliminated and the gas bladder had enlarged (Fig. 6C). By day 30, spines began developing in the first dorsal fin, pelvic fins began developing, the stomach had enlarged, and a pyloric caecum began developing posterior to the stomach (Fig. 7A). By day 32, the larvae had completed transition to the metalarvae phase (15.0 mm); all principal fin rays had formed and the stomach, pyloric caeca, and gas bladder had enlarged (Fig. 7B).

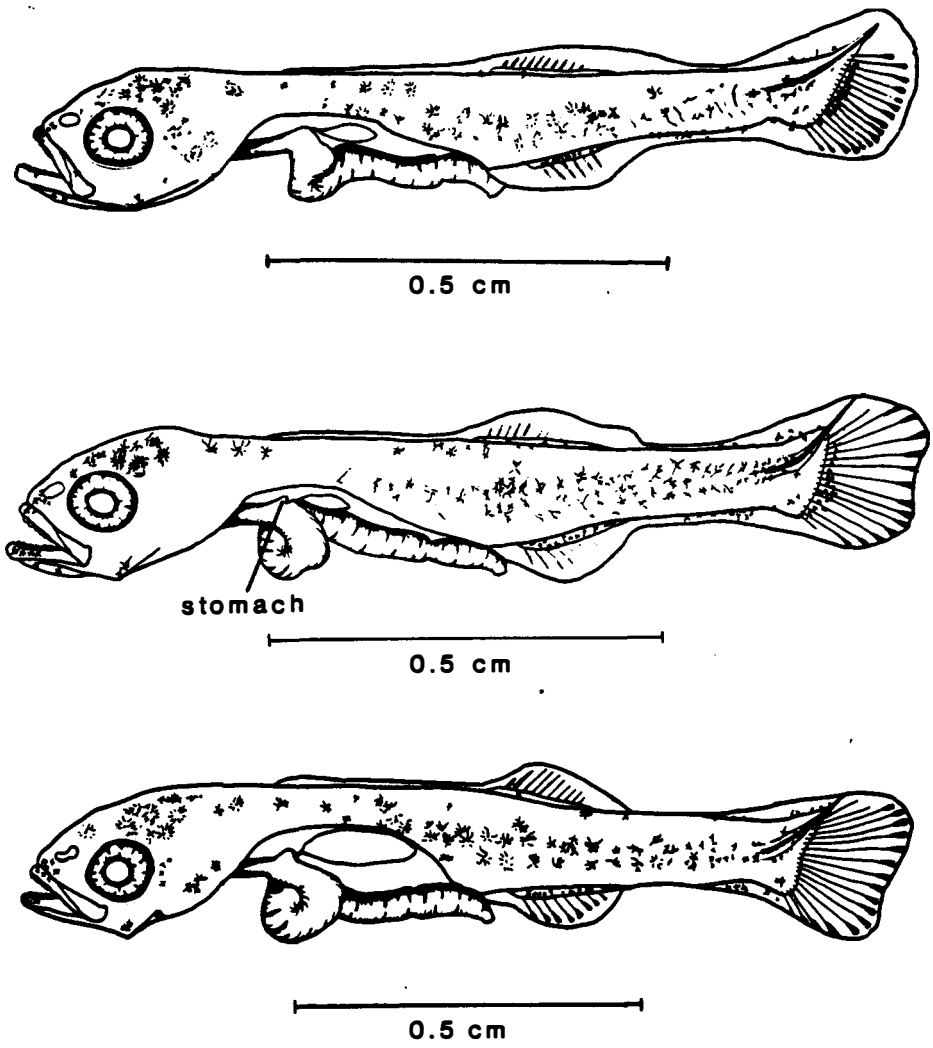

Fig. 6. Alimentary canal development of yellow perch (Perca flavescens) larvae; (A) Mesolarvae, 11.3 mm; (B) Mesolarvae, 11.7 mm; (C) Mesolarvae, 12.8 mm (abdominal walls, gills, and livers removed).

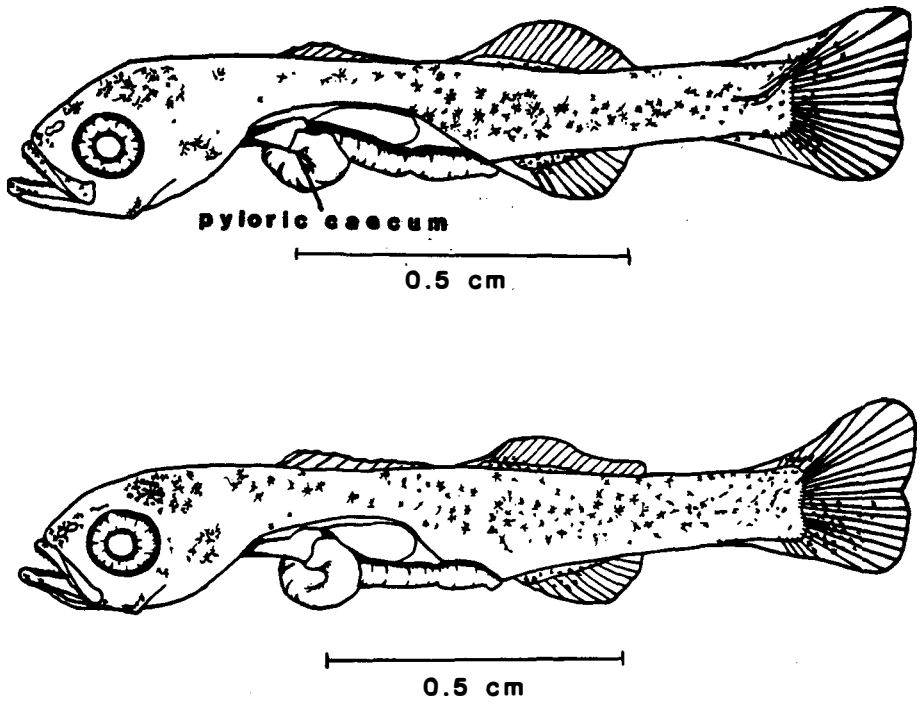

Fig. 7. Alimentary canal development of yellow perch (Perca flavescens) larvae; (A) Late mesolarvae, 13.4 mm; (B) Recently transformed metalarvae, 15.0 mm (abdominal walls, gills, and livers removed).

DISCUSSION

Increased production of intensively reared walleyes may be obtained if larval survival can be increased. Initial stocking rates warrant additional attention since higher survival rates occurred in tanks stocked at 35/liter than at 17/liter. Covering the lower one-half of rearing tanks to concentrate larvae during initial feeding was not beneficial since the lowest survival occurred, and significantly ($P<.05$) fewer organisms were ingested by walleyes in those tanks.

Survival of larval walleyes in the present study was greater or similar to those reported for other studies. Howey et al. (1980) reported 43.5% survival of larvae fed brine shrimp supplemented with Daphnia sp. for a three week period; however, they also reported a possible nutritional deficiency during extensive brine shrimp feeding since a difference was observed in the swimming and feeding behavior between these fish and pond reared fish. Beyerle (1980) reported less than 4.0% survival of larvae fed either a combination of brine shrimp and Daphnia pulex or prepared diets for a three week period. Olsen (1974) reported less than 0.5% survival of larvae fed invertebrates collected from a lake for a 11 day period.

Several factors contribute to the high mortality of larval walleyes reared intensively. Cannibalism appeared to be one of the major factors. Cuff (1980) and Howey et al. (1980) reported that cannibalism commences the day of initial exogenous feeding which is similar to that observed in the present study. Olsen (1974) found cannibalism by intensively reared walleyes so severe that less than 0.5% survived

more than two weeks. In the present study, cannibalism accounted for a high percentage of the mortality during the first 18 days of rearing. Greater food availability does not appear to control cannibalism since abundant food was available during the present study.

Another factor limiting survival of walleye larvae is high mortality before initial exogenous feeding. In the present study, 30% of the larvae died before yolk sac absorption and initial feeding which was similar to what Howey et al. (1980) reported. Mortality during this period may be due to a percentage of abdormal fish which do not develop.

Walleyes in the present study grew to a length of 46.6 mm in 50 days which compares favorably to that reported in other studies. Smith and Moyle (1945) reported walleyes from Minnesota rearing ponds averaged 48.1 mm in length after 50 days of rearing. Beyerle (1975) found walleyes that were fed brine shrimp and Dahpnia sp. averaged 22.9 mm in length after 32 days. Spykerman (1974) reported walleyes in Clear Lake, Iowa reached 33 mm in length after 30 days.

Initial feeding by walleye larvae less than 10 mm long was different than that reported in some other studies. Hohn (1966) and Paulus (1969) reported diatoms were the first food of larvae less than 9.0 mm long in Lake Erie, and Smith and Moyle (1945) reported rotifers of the genera Asplanchna, Brachionus, and Keratella were important in the initial diet of walleyes from Minnesota rearing ponds. In the present study, initial food was similar to what Houde (1967) and Spykerman (1974) found. Houde (1967) reported rotifers were not important in the diet of larvae from Oneida Lake, New York; copepods were the most important food

item. Spykerman (1974) found that larvae from Clear Lake, Iowa did not start feeding until they reached 9.0 mm long and rotifers were not consumed. He also reported that cladocerans comprised the majority of the food ingested but were selected against and that copepods were selected for. Merna (1977) also found that cladocerans were the initial food of walleye larvae from Michigan ponds.

Food of walleyes greater than 10 mm long in the present study was similar to that reported in other studies. Smith and Moyle (1945) reported walleyes less than 20 mm long fed upon larger cladocerans Daphnia pulex and Simocephalus sp. Hohn (1966) reported that Cyclops bicuspidatus and Bosmina longirostris were important food items of walleye 9-14 mm long from Lake Erie. Priegal (1969) reported that walleyes 10-50 mm long fed primarily upon Diaptomus sp. and Leptodora sp. Houde (1967) and Spykerman (1974) reported that cladocerans were ingested but selected against, and that Cyclops sp. was selected for by walleyes greater than 10 mm long.

Ivlev (1961) reported that food selectivity by fish also depends upon food size. Although size selection of organisms by larger fish has been demonstrated by numerous investigators (Brooks and Dodson 1965; Galbraith 1967; Hansen and Wahl 1981), prey size selection by walleyes has not been thoroughly investigated. Initial size selection by walleye larvae may be limited by mouth gape; Wong and Ward (1972) reported that mouth gape limited initial food size of yellow perch. Walleyes in the present study ingested cladocerans of a size similar to that reported by Spykerman (1974) and Merna (1977). Spykerman (1974) found that walleyes (9.0-9.9 mm long) ingested Daphnia sp. that averaged 0.86 mm

long and as walleyes grew they ingested progressively larger Daphnia sp. Merna (1977) found that the mean length of Bosmina longirostris in larval walleye stomachs was longer than the mean length of those in plankton samples, and the mean length of Daphnia pulex in stomachs was smaller than the mean length in plankton samples. Howey et al. (1980) reported brine shrimp 0.4 mm long were ingested by walleyes less than 20 mm long and 0.6-1.0 mm Daphnia sp. were not ingested. Walleyes in the present study ingested progressively longer cladocerans but not progressively longer C. vernalis. Linear forage ratios indicated that walleyes, during different developmental phases, selected for certain size organisms.

Differences in the mean number of food items ingested by larval walleyes collected at 1100 and at 2300 hours may be due to the mode of feeding. Initially, more food items were ingested by larvae collected at 1100 hours than those at 2300 hours. During this time, the eyes are not as fully developed (Blaxter 1969) and the alimentary canal is changing. After day 15, more organisms were ingested by larvae collected at 2300 hours than at 1100 hours which may have been due to the development of the eyes and other systems.

Initial size of yellow perch at first feeding (6.0 mm long) was similar to what Siefert (1972) reported for yellow perch from two lakes. Initial food ingested was similar to that reported by other studies. Siefert (1972) found that the rotifer, Polyarthra sp., and copepod nauplii were important items in the diet of larvae less than 11 mm long from an oligotrophic lake, and copepod nauplii and cyclopoid copepods were important in the diet of larvae from an eutrophic lake. He also

reported that Bosmina sp. was important in the diet of larvae greater than 11.0 mm long. Bulkley et al. (1976) reported that yellow perch (8.7 mm long) from Clear Lake, Iowa fed primarily upon copepods but also ingested the rotifer, Keratella sp., and cladocerans; larvae (13.1 mm long) fed primarily upon copedpods. Guma'a (1978) reported that the Eurasian perch (Perca fluviatilis) initially fed upon algae, rotifers, and copepod nauplii, but after they attained 7.0 mm in length they ingested Bosmina obtusirostris and Daphnia hyalina var. galeata. He also found that B. obtusirostris was selected for while Cyclops sp. was selected against.

A number of factors may influence initial prey selection by yellow perch. Some of these may be prey availability, color, mode of swimming, and mouth gape. Brachionus sp. may have been selected for less at 2300 than at 1100 hours because of its small size, which may make it difficult to locate during darkness. Moina brachiata may have been selected for more at 2300 than at 1100 hours because it may have been easier to locate and capture because of its larger size and slow movement. Cyclops vernalis may have been selected for by fish collected at 2300 than at 1100 hours due to it avoiding fish predation during light hours; Applegate (1981) reported that C. vernalis was selected for more by muskellunge larvae collected at 2300 than at 1300 hours.

Little information is available on the size of food ingested by larval yellow perch. Wong and Ward (1972) reported that larvae cannot ingest Daphnia pulicaria, 1.3 mm long until the larvae reach 18.0 mm in length; mouth gape initially limits size of food ingested. Hansen and Wahl (1981) found that the mean length of Daphnia pulex in yellow

perch, (20-51 mm long) stomachs was smaller than those in plankton samples indicating size selection by fish. In the present study, yellow perch larvae ingested progressively longer cladocerans but only ingested the smaller instars during the first 25 days of feeding.

A number of factors have to be considered when indicating selection of food types by fish, such as differential rates of prey capture efficiency, differential rates of prey encounter due to variable prey visability, and optimal foraging where a predator ignores certain inferior prey individuals (Eggers 1977). Differences in food ingested by larvae between studies may be due to these factors or fish may be ingesting the only available prey. Walleyes and yellow perch in the present study may have selected M. brachiata because of its color, slow movement, and optimal size. Brooks (1959) described M. brachiata as a small, soft bodied cladoceran that is widely distributed in pools. Applegate (1981) found that M. brachiata was selected for by muskellunge larvae. Daphnia magna and D. pulex may have been selected against because of their large size and tough carapace which may make them difficult to ingest; Nagel (1976b) reported that D. magna lodges in the esophagus of muskellunge larvae and causes death. Asplanchna sieboldi may have been selected against due to its large size and transparent body which may make it difficult to detect (Costa and Cummins 1972).

The development of the alimentary canal of walleye and yellow perch larvae was accompanied by fin development which was used as a criterion for differentiating phases of larval fish (Synder 1976). Applegate (1982) used this system to differentiate phases of alimentary canal development of muskellunge larvae. External development of

the larvae in the present study was similar to that reported from previous studies (Fish 1932; Mansuetti 1964; Norden 1961; Nelson 1968; Spanovshaya and Grygorash 1977).

The alimentary canal enlarges and completes a loop during the protolarvae phase; no fin rays are present. During the mesolarvae phase, the stomach and pyloric caeca develop; fin rays develop in the median fins. During the metalarvae phase, the stomach and pyloric caeca enlarge; fin ray formation is completed and pelvic fins develop. Nelson (1968) reported that three pyloric caeca were present in walleye larvae 19 mm in length which corresponds with the present study. The alimentary canal development of yellow perch was similar to the alimentary canal development of the Eurasian perch (Spanovshaya and Grygorash 1977).

In conclusion, attempts to rear walleye and yellow perch larvae intensively by feeding various prepared diets and live zooplankton have generally been unsuccessful in the past. The main problem has been providing a food that is ingested by the larvae and that will meet their nutritional requirements. The present study demonstrated that walleyes and yellow perch can be reared intensively by feeding invertebrates collected from a municipal sewage lagoon, and that they selected for a cladoceran, M. brachiata, which commonly predominates in wastewater stabilization ponds.

LITERATURE CITED

Applegate, R.L. 1981. Food selection of muskellunge fry. The Progressive Fish-Culturist 43:136-139.

Applegate, R.L. 1982. Alimentary canal development of muskellunge, Esox masquinongy. Copeia:717-719.

Beyerle, G.G. 1975. Summary of attempts to raise walleye fry and fingerlings on artificial diets, with suggestions on needed research and proceedures to be used in future test. The Progressive Fish-Culturist 37:103-105.

Beyerle, G.G. 1980. Intensive culture of walleye fry and fingerlings in Michigan, 1972-1979. Reports of the 1979 coolwater diet testing steering committee meeting. Wellsboro, Pennsylvania, USA.

Blaxter, J.H.S. 1969. Development of eggs and larvae. Pages 177-252 in W.S. Hoar and D.J. Randall, editors. Fish physiology, volume 3. Academic Press, New York, New York, USA.

Brooks, J.L. 1959. Cladocera. Pages 587-656 in W.T. Edmondson, editor. Fresh-Water biology, 2nd edition. John Wiley & Sons, Inc. New York, New York, USA.

Brooks, J.L., and S.I. Dodson. 1965. Predation, body size, and composition of plankton. Science 150:28-35.

Bulkley, R.V., V.L. Spykerman, and L.E. Inmon. 1976. Food of pelagic young walleyes and five cohabiting fish species in Clear Lake, Iowa. Transactions of the American Fisheries Society 105:77-83.

Cheshire, W.F., and K.L. Steele. 1972. Hatchery rearing of walleye using artificial food. The Progressive Fish-Culturist 34:96-99.

Costa, R.R., and K.V. Cummins. 1972. The contribution of Leptodora and other zooplankton in the diet of various fish. American Midland Naturalist 87:559-564.

Cuff, W.R. 1980. Behavioral aspects of cannibalism in larval walleye, Stizostedion vitreum vitreum. Canadian Journal of Zoology 58: 1504-1507.

Dewitt, J.W., and W. Candland. 1971. The water flea. The American Fish Farmer 3:8-11.

Eggers, D.M. 1977. The nature of prey selection by planktivorous fish. Ecology 58:46-59.

Fish, M.P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. United States Department of Commerce, Bureau of Fisheries Bulletin 47: 293-398.

Forney, J.L. 1966. Factors affecting first year growth of walleyes in Oneida Lake, New York. New York Fish and Game Journal 13:146-167.

Galbraith, M.G. Jr. 1967. Size-selective predation on Daphnia by rainbow trout and yellow perch. Transactions of the American Fisheries Society 96:1-10.

Guma'a, S.A. 1978. The food and feeding habits of young perch, (Perca fluviatilis) in Windermere. Freshwater Biology 8:177-187.

Hale, J.G., and A.R. Carlson. 1972. Culture of yellow perch in the laboratory. The Progressive Fish-Culturist 34:195-198.

Hansen, M.J., and D.H. Wahl. 1981. Selection of small Daphnia pulex by yellow perch fry in Oneida Lake, New York. Transactions of the American Fisheries Society 110:64-71.

Hohn, M.H. 1966. Analysis of plankton ingested by Stizostedion vitreum vitreum (Mitchell) fry and concurrent vertical plankton tows from Southeastern Lake Erie, May 1961 and May 1962. Ohio Journal of Science 66:193-197.

Houde, E.D. 1967. Food of pelagic young of the walleye, Stizostedion vitreum vitreum, in Oneida Lake, New York. Transactions of the American Fisheries Society 96:17-24.

Howey, R.G., G.L. Theis, and P.B. Haines. 1980. Intensive culture of walleye (Stizostedion vitreum vitreum). Lamar Fish Culture Development Center Leaflet Number 80-05.

Huh, H.T., H.E. Calbert, and D.A. Sturber. 1976. Effects of temperature and light in growth of yellow perch and walleye using formulated feed. Transactions of the American Fisheries Society 105:254-258.

Ivlev, V.S. 1961. Experimental ecology of the feeding of fishes. Yale University Press, New Haven, Connecticut, USA (Translated from Russian by D. Scott).

Mansuetti, A.J. 1964. Early development of the yellow perch, Perca flavescens. Chesapeake Science 5:46-66.

May, R.C. 1974. Larval mortality in marine fishes and the critical period concept. Pages 3-20, in J.H.S. Blaxter, editor. The early life history of fish. Springer-Verlag, New York, New York, USA.

Merna, J.W. 1977. Food selection by walleye fry. Michigan Department of Natural Resources, Fisheries Research Report Number 1847.

Nagel, T.O. 1974. Rearing of walleye fingerlings in an intensive culture using Oregon Moist pellets as an artificial diet. The Progressive Fish-Culturist 36:59.

Nagel, T.O. 1976a. Intensive culture of fingerling walleyes on formulated feeds. The Progressive Fish-Culturist 38:90-91.

Nagel, T.O. 1976b. Technique for collecting newly hatched fathead minnow fry. The Progressive Fish-Culturist 38:137.

Nelson, W.R. 1968. Embryo and larval characteristics of sauger, walleye, and their reciprocal hybrid. Transactions of the American Fisheries Society 97:167-174.

Nickum, J.G. 1978. Intensive culture of walleyes: the state of the art. Pages 187-197 in R.L. Kendell, editor. Selected coolwater fishes of North American. American Fisheries Society Special Publication 11.

Norden, C.R. 1961. The identification of larval yellow perch, Perca flavescens, and walleyes, Stizostedion vitreum vitreum. Copeia 1961:282-288.

Olsen, D.E. 1974. Effects of elevated temperature and fry density on initiation of feeding by walleye fry. Minnesota Department of Natural Resources, Investigation Report Number 327.

Parsons, J.W. 1971. Selective food preferences of walleyes of the 1959 year class in Lake Erie. Transactions of the American Fisheries Society 100:474-485.

Paulus, R.D. 1969. Walleye fry food habits in Lake Erie. Ohio Fish Monograph 2.

Phyca, R.L., and L.L. Smith, Jr. 1955. Early life history of the yellow perch, Perca flavescens (Mitchell), in Red Lakes, Minnesota. Transactions of the American Fisheries Society 84:249-260.

Priegal, G.R. 1969. Food and Growth of young walleyes in Lake Winnebago, Wisconsin. Transactions of the American Fisheries Society 98: 121-124.

Reinitz, G., and R. Austin. 1980. Experimental diets for intensive culture of yellow perch. The Progressive Fish-Culturist 42:29-32.

Sampson, E.O. 1955. A double duty oxidation pond. Sewage and Industrial Wastes 27:1410-1415.

Seaburg, K.B., and J.B. Moyle. 1964. Feeding habits, digestive rates, and growth of some Minnesota warmwater fishes. Transactions of the American Fisheries Society 93:269-285.

Siefert, R.E. 1972. First food of larval yellow perch, white sucker, bluegill, emerald shiner, and rainbow smelt. Transactions of the American Fisheries Society 101:219-225.

Smith, L.L., and J.B. Moyle. 1943. Factors influencing production of yellow pike-perch, Stizostedion vitreum vitreum, in Minnesota rearing ponds. Transactions of the American Fisheries Society 73:243-261.

Snyder, D.E. 1976. Terminologies for intervals of larval fish development. Pages 41-58 in J. Boreman, editor. Great Lakes fish and egg and larvae identification. Proceedings of a workshop. United States Fish and Wildlife Service. FWS/OBS-76/23.

Spanovshaya, V.D., and V.A. Grygorash. 1977. Development and food of age-0 Eurasian perch (Perca fluviatilis) in reservoirs near Moscow, U.S.S.R. Journal of Fisheries Research Board of Canada 34:1551-1558.

Spykerman, V.L. 1974. Food habits, growth, and distribution of larval walleye, Stizostedion vitreum vitreum (Mitchell), in Clear Lake, Iowa. Proceedings of the Iowa Academy of Science 81:143-149.

Strauss, R.L. 1979. Reliability estimates for Ivlev's electivity index. the forage ratio, and a proposed linear index of food selection. Transactions of the American Fisheries Society 108:344-352.

Wolfert, R.R. 1966. Food of young of the year walleyes in Lake Erie. United States Fish and Wildlife Service, Fisheries Bulletin 65: 489-94.

Wong, B., and F.J. Ward. 1972. Size-selection of Daphnia pulicaria by yellow perch (Perca flavescens) fry in the West Blue Lake, Manitoba. Journal of Fisheries Research Board of Canada 29:1761-1764.

APPENDIX

Appendix Table 1. Analysis of variance of the mean survival of walleye larvae between tanks stocked with 2000 larvae, 4000 larvae, and 4000 larvae and covered, during the first 18 days of rearing, 7 May-25 May 1981.

Source of Variation	Degree of Freedom	Mean Square	F
Treatment	2	0.020	1.58
Error	5	0.012	

Appendix Table 2. Analysis of variance of the mean unaccountable mortality of walleye larvae between tanks stocked with 2000 larvae, 4000 larvae, and 4000 larvae and covered, during the first 18 days of rearing, 7 May-25 May 1981.

Source of Variation	Degree of Freedom	Mean Square	F
Treatment	2	0.035	2.22
Error	5	0.016	

Appendix Table 3. Analysis of variance of the mean number of organisms ingested by walleyes collected at 1100 and 2300 hours, between tanks stocked with 2000 larvae, 4000 larvae, and 4000 larvae and covered, during the first 12 days of feeding, 12 May-25 May 1981.

Source of Variation	Degree of Freedom	Mean Square	F
Day	11	34.64	5.51 *
Time	1	84.37	13.43 *
Day * Time	11	18.13	2.89 *
Level	2	38.57	6.14 *
Day * Level	22	6.18	0.98
Time * Level	2	6.50	1.03
Day * Time * Level	22	7.03	1.12
Error	144	6.28	

*Significant at the .05 level of probability.

Appendix Table 4. Analysis of variance of the mean number of organisms ingested by walleyes collected at 1100 and 2300 hours during days 13-24 of feeding, 26 May-5 June 1981.

Source of Variation	Degree of Freedom	Mean Square	F
Day	11	8.15	2.85 *
Time	1	220.03	7.69 *
Day * Time	11	95.95	3.35 *
Error	120	28.62	

*Significant at the .05 level of probability.

Appendix Table 5. Analysis of variance of the mean length of cladocerans ingested by yellow perch collected at 1100 and 2300 hours during the first 18 days of feeding, 12 May-31 May 1981.

Source of Variation	Degree of Freedom	Mean Square	F
Day	17	0.041	3.45 *
Time	1	0.010	0.85
Day * Time	16	0.010	1.47
Error	246	0.012	

*Significant at the .05 level of probability.

Appendix Table 6. Analysis of variance of the mean number of Brachionus sp. ingested by yellow perch collected at 1100 and 2300 hours during the first 18 days of feeding, 12 May-31 May 1981.

Source of Variation	Degree of Freedom	Mean Square	F
Day	23	70.48	2.01 *
Time	1	1255.76	35.86 *
Day * Time	23	51.93	1.48
Error	191	35.02	

*Significant at the .05 level of probability.

Appendix Table 7. Analysis of variance of the mean number of organisms other than Brachionus sp. ingested by yellow perch collected at 1100 and 2300 hours during the first 18 days of feeding, 12 May-31 May 1981.

Source of Variation	Degree of Freedom	Mean Square	F
Day	23	72.15	2.21 *
Time	1	317.88	9.74 *
Day * Time	23	51.84	1.59
Error	191	32.64	

*Significant at the .05 level of probability.